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3. Brian Brisco, Fawwaz T, Ulaby and Craig Dobson

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WITHIN-FIELD VARIABILITY OF PLANT AND SOIL PARAMETERS

Remote Sensing Laboratory
RSL Technical Report 360-16

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December 1981

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ABSTRACT

For research and development as well as applications-oriented studies in remote sensing, sub-units, called test sites, are used to describe the areas being studied. It is desirable to obtain enough measurements for any given variable to be able to confidently describe the mean and standard deviation. The results reported in this paper indicate that eight samples may be adequate for plant height determinations whereas approximately 20 samples are needed for plant- and soil-moisture characterization. A sampling intensity of 18 was found to be suitable for detecting within-field variability over time and between-field variability for the same crop. Although the gathering of this many samples may be impractical, it appears to be necessary to confidently describe the means and standard deviations of the variables measured in this experiment. The results also indicate that the necessary sample sizes may vary according to (1) the physiological growth stage of the crop, and (2) recent weather events that may affect the moisture and/or height characteristics of the field in question.

1.0 INTRODUCTION

The value of using remote sensing techniques to monitor the earth's surface has received much attention in the past decade. Applications related to studies of snow, soil moisture, agricultural productivity, geology, etc., have been proposed, and in some cases implemented during this period of rapid development. In the future, continued development and increased use of these techniques can be expected.

Ground investigations of the area to be remotely sampled are used to evaluate the sensor's output for both research and development and applications-oriented studies. The types of ground investigations performed in support of remote sensing studies are summarized by Reeves (1975). In general, small areas are selected from the entire area to serve as test sites for sampling purposes. Therefore, an important question to consider is whether the test sites adequately represent the entire area being investigated. For any given variable to be measured, statistical procedures can be used to determine the sampling intensity required to describe the mean and standard deviation. However, constraints on manpower, time, equipment, and other resources usually prevent this approach.

The Remote Sensing Laboratory (RSL) has been investigating the microwave interaction with vegetation media for the past eight years. Radar backscatter behavior as a function of the geometrical and electrical properties of vegetation, and the use of radar for crop identification have been studied (Ulaby, 1981). Although the sampling techniques for ground-truth data acquisition in soil moisture studies have been evaluated (Rao, 1976), a similar study has not been conducted for the

vegetation experiments.

This report investigates the variability of ground-truth data collected for vegetation experiments conducted at the RSL. Two different fields of wheat and a field of corn were sampled on two dates to provide a data base for this study. The variability of crop- and soil-parameters within a field, between two fields of the same crop type, and within a field over time were compared statistically. The results were used to evaluate ground-truth sampling programs carried out in support of vegetation studies and to make recommendations for future experiments.

2.0 GROUND TRUTH DATA COLLECTION

The test site used for this experiment is located in the Kansas River floodplain near the confluence of the Kansas River and the Wakarusa River east of Lawrence, Kansas. This area is characterized by a diverse assemblage of soils with a variety of crop types present, and is the site of current RSL experiments involving crop-discrimination and soil-moisture studies. Wheat 4 and Corn 6 were both located on a silt-loam soil while Wheat 8 was on a sandy-loam soil. The two wheat fields were sampled on June 10 and 17, 1981, while the corn field was visited on June 17 and 30.

Each field was sampled in the same way, as follows: A 40-meter swath was identified on the road-side of the field by means of surveyor flags. The ground-truth team was composed of six individuals split into three groups of two individuals each. From the start of the identified swath they proceeded directly into the field for a distance of 35 meters. Using this location as a reference point, three plots of 10 m x 10 m,

each separated by 5 meters, were marked out. One team then proceeded to each of these plots to sample plant height, soil moisture, and plant moisture. For the wheat fields both spike height and leaf height were recorded. Figure 1 illustrates the plot- and sampling-locations within a field.

Each field worker sampled each variable three times, giving rise to six samples per plot and eighteen samples per field. Sample locations were randomly chosen by each individual within his respective plot. Plant- and spike-heights were measured to the nearest CM using a meter stick. Soil samples were collected with a trowel for the 0-5-cm depth and stored in plastic coffee cups for later gravimetric moisture analysis. One corn plant per sample location was obtained for gravimetric moisture determination while half a linear-foot of row was sampled in the wheat fields.

3.0 STATISTICAL ANALYSIS

Due to the paucity of data points (3) per individual, within-plot variability could not be evaluated. The data collected by each pair of individuals were then pooled on a plot basis. The same pair of individuals visited the same plots in each field so that the comparison of the six samples for each variable from any given plot would be valid. All statistical analyses were performed using the SPSS system of computer programs (Nie et al., 1975; Nie and Hall, 1981).

Nonparametric statistics were used as there were not enough observations to specify the distributions of the variables. The one-way analysis of variance developed by Kruskal and Wallis (1952) was used to determine whether all plots within a field were from the same populations. To

x-Individual #1 Sampling Locations
 ●-Individual #2 Sampling Locations } Chosen at Random

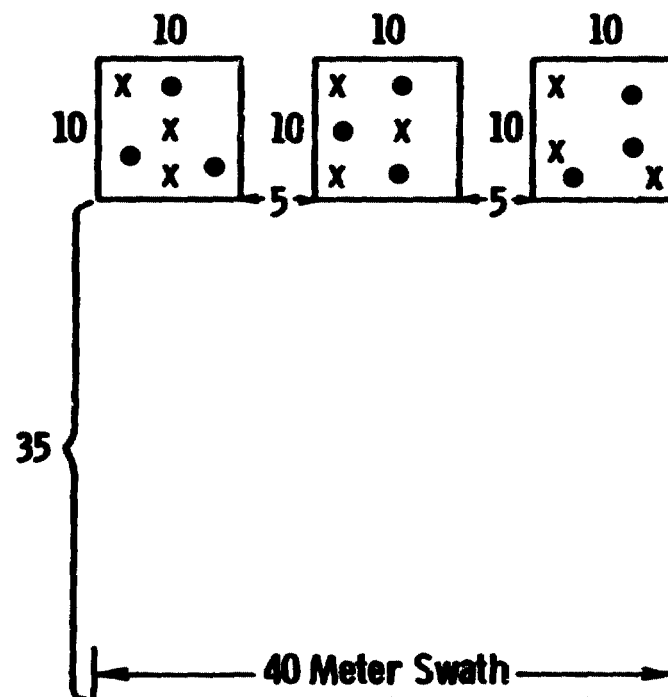


Figure 1. Location of Plots and Sampling Sites Within a Field. (All Distances in Meters)

find out if there were significant differences in a variable between the two wheat fields, the Mann-Whitney mean test (Mann and Whitney, 1947) was applied. The Wilcoxon matched-pairs ranked-signs test was used to checked for differences between the same variable in a field on two different dates (Wilcoxon, 1945). Between-field differences for the wheat fields were also determined using the classical T-test for independent samples. Similarly, the T-test for dependent samples was employed to further investigate differences between the same variable in one field at two different times.

4.0 RESULTS AND DISCUSSION

The field data for the wheat fields are presented in Table 1 and for the corn field in Table 2. Computer outputs for the various statistical tests can be found in Appendix I. Results from the Kruskal-Wallis one-way ANOVA (Table 3) indicate that in approximately half of the cases there was a significant difference between plots within a field. Spike height exhibited the greatest variability, with four out of the six cases indicating significant differences. Plant water content, leaf height, and soil moisture were significantly different 50 percent of the time.

The results in Table 3 also indicate that Wheat 8 changes from conditions of low variability on June 10 to high variability on June 17 for the variables measured. Wheat 4 shows mixed results, with similar field variability between the two dates, but for exactly opposite plant/soil variables. Corn 6 exhibits high variability on both dates for the three variables measured. These results indicate that a sample size greater than six per field is needed to confidently determine the mean of the variables observed in this experiment.

The calculated means (\bar{M}) and standard deviations ($\bar{s}\bar{d}$) reported in Tables 1 and 2 can be used to estimate the sampling intensity required to accurately determine the mean 90 percent of the time. The formula used to calculate this sampling intensity is

$$N = \left(\frac{\sqrt{18} \times \bar{s}\bar{d}}{\bar{M} \times .1} \right)^2$$

where

N = estimated sampling intensity

$\sqrt{18}$ = sample size for estimates of \bar{M} and $\bar{s}\bar{d}$

$\bar{s}\bar{d}$ = standard deviation from Tables 1 and 2

\bar{M} = mean from Tables 1 and 2

Table 4 presents the estimated sampling intensities obtained using this expression.

These results indicate that 68 percent of the variables measured during this experiment require a sample size of fewer than 18 for estimating the mean and standard deviation. The average estimated sample size for these variables is 8. In general, smaller sample sizes are needed for plant-height measurements compared to plant- or soil-moisture observations. Soil moisture is quite variable and thus a larger sample size is needed to estimate the mean and standard deviation. Rao (1976) reports sample sized of 11-32 for the 0-5-cm depth in a 2½-acre field, which is similar to the average number of 20 reported in Table 4. Crop moisture in the corn fields is quite uniform during the growth stage (vegetative) that the plants were in during this experiment. Thus, small sample-sizes will adequately describe the mean and standard deviation. However, the wheat fields were maturing during this experiment and thus moisture conditions were changing. This is reflected in the

sample sizes reported in Table 4.

Since the means and standard deviations used to estimate the sample sizes reported above are based on a small sample-size (18), the estimated sampling intensity must not be considered absolute. However, the results indicate approximately the number of samples that is required to accurately describe the variables measured in this experiment. It appears that height characteristics should be estimated using sample sizes of 6-10 while the moisture estimates require more samples (12-20) for accurate determinations. The sampling intensity will also be a function of the growth stage of the crop in question, as well as recent weather events.

Between-field variability for the two wheat fields was assessed using both nonparametric tests and the classical T-test procedure for independent samples. The results (Table 4) are the same for both approaches and indicate no significant difference between fields for spike height and leaf height on June 10. In all other cases, the means for the observed variables are significantly different at the 99-percent confidence level.

At this time of year, the wheat crops are approaching maturity and little change in plant growth is expected. The significant difference in the plant-height variables found on June 17, but not on June 10, may be due to crop damage caused by bad weather in late May and early June. More damage, from wind and rain, was observed in Wheat 4 than in Wheat 8 on the June 10 sample data. By June 17, Wheat 8 had recovered to a greater extent than had Wheat 4. Although the sample size appears to be too small for within-field variability analysis of plant- and soil-moisture differences, the highly significant results reported in Table 4 indicate that the pooled samples are sufficient to detect between-field differences.

The results of the comparisons within a field over time are presented in Table 5. Very similar results are found using parametric versus nonparametric statistical procedures. The argument presented above for between-field variability in wheat-plant height variables can be applied to the results in Table 5. Similarly, it appears that the pooled sampling intensity is large enough to detect differences in the other variables within a field over time. This is expected for the moisture variables, as rainfall events and changes in plant maturity occurred during the time period of the experiment. Corn is in a vegetative stage of growth at this time of year and thus is rapidly increasing in height. This change is readily detected using the sampling intensity method and methods reported above, as the 99-percent significant level in Table 5 indicates.

Thus it appears that six samples per field is an inadequate number to determine the mean of the plant-soil variables observed in this experiment. Height characteristics can be estimated with approximately eight samples while approximately 20 samples are needed for moisture estimates of plants and soil. These sample sizes may vary according to (1) the growth stage of the field in question, and (2) recent environmental events such as rainfall. A sample size of 18 appears to be suitable for detecting between-field variability and temporal within-field variability of the measured plant-soil variables. Although this sampling intensity might often be impractical, it may be necessary to produce reliable quantitative results. An experiment needs to be conducted, with a larger sample size than was used in this effort, to more accurately determine within-field variability for these plant-soil parameters.

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TABLE 1
Field Data for Wheat Fields # 4 and 8

FIELD #	PLOT #	SAMPLE #	June 10				June 17			
			SPIKE HEIGHT	LEAF HEIGHT	PLANT H ₂ O	SOIL H ₂ O	SPIKE HEIGHT	LEAF HEIGHT	PLANT H ₂ O	SOIL H ₂ O
W4	1	1	96	70	47.57	33.79	106	66	37.14	37.00
		2	98	70	55.24	31.83	92	61	35.25	34.72
		3	105	70	52.65	33.33	103	72	42.11	40.71
		4	97	65	52.39	29.90	98	66	37.88	36.17
		5	96	73	54.60	31.92	105	73	67.24	42.22
		6	94	67	55.20	35.22	100	78	55.29	38.83
	2	1	97	72	51.17	27.32	111	74	32.49	37.50
		2	98	70	51.02	36.73	95	68	35.50	35.51
		3	102	78	53.02	33.02	91	63	40.45	36.90
		4	105	75	56.13	36.17	95	75	37.47	37.38
		5	104	82	51.87	34.16	95	74	40.08	36.53
		6	98	72	61.48	32.92	96	73	34.93	35.91
	3	1	105	74	55.87	38.80	93	74	40.38	41.12
		2	101	76	54.81	35.48	91	64	41.99	36.18
		3	106	75	55.80	37.80	92	67	43.27	39.12
		4	105	79	56.41	36.61	85	65	37.06	36.97
		5	99	69	53.32	33.95	88	68	43.73	39.98
		6	98	76	53.69	36.63	92	67	41.15	38.00
	MEAN		99.94	72.94	54.01	34.20	96.0	69.33	41.30	37.82
	STANDARD DEV.		4.17	4.36	2.93	2.87	6.73	4.85	8.16	2.09
W8	1	1	100	70	43.27	20.64	70	57	13.08	36.89
		2	98	63	45.40	24.41	78	48	12.16	24.12
		3	95	73	44.16	17.77	80	54	16.41	25.23
		4	94	58	49.29	22.24	85	49	18.37	24.44
		5	97	69	49.19	21.06	67	41	8.50	20.96
		6	102	68	48.31	19.58	74	46	6.57	24.07
	2	1	92	65	54.84	21.38	91	60	16.79	22.96
		2	99	60	55.41	19.38	82	63	21.90	22.61
		3	97	55	50.26	21.90	80	58	24.37	24.08
		4	108	79	44.46	19.71	90	61	20.60	24.60
		5	98	75	43.98	20.94	77	64	21.02	23.31
		6	101	72	47.09	21.51	84	62	17.97	22.63
	3	1	89	63	43.99	20.82	86	60	17.98	23.82
		2	111	74	53.82	21.65	92	73	27.78	24.31
		3	113	86	53.31	25.03	83	63	20.74	22.93
		4	100	70	46.99	21.56	91	66	31.26	22.95
		5	111	81	50.95	17.63	95	68	27.41	22.48
		6	108	78	45.39	24.89	96	68	30.14	22.42
	MEAN		100.72	69.94	48.34	21.20	83.39	58.94	19.58	24.16
	STANDARD DEV.		6.89	8.31	4.03	2.08	8.29	8.48	6.95	3.34

TABLE 2
Field Data for Corn Field #6

FIELD #	PLOT #	SAMPLE #	June 17			June 30		
			SPIKE HEIGHT	PLANT H ₂ O	SOIL H ₂ O	SPIKE HEIGHT	PLANT H ₂ O	SOIL H ₂ O
C6	1	1	188	89.73	21.99	275	82.22	24.82
		2	191	90.73	22.01	273	81.65	24.77
		3	186	91.33	19.57	274	81.94	30.76
		4	195	91.07	23.20	285	82.14	28.13
		5	175	91.54	22.22	283	91.63	31.24
		6	190	92.01	22.19	280	81.75	28.82
	2	1	195	90.90	22.42	264	83.89	25.93
		2	192	92.43	24.77	255	82.00	26.81
		3	193	93.03	25.40	270	80.60	22.86
		4	185	92.46	19.99	268	83.82	23.09
		5	200	92.41	19.24	260	83.21	21.77
		6	179	92.12	20.72	290	83.00	23.28
	3	1	161	93.79	19.69	264	79.91	24.91
		2	183	90.80	20.04	256	83.88	28.52
		3	181	90.72	17.02	265	83.81	27.32
		4	169	91.57	20.66	270	82.44	24.17
		5	163	90.42	17.70	267	81.43	28.50
		6	161	92.12	15.52	250	79.59	28.02
	MEAN		182.61	91.62	20.80	269.39	82.76	26.32
	STANDARD DEV.		12.29	1.02	2.55	10.76	2.58	2.77

TABLE 3
Kruskal-Wallis One-Way ANOVA Results
for Wheat Fields #4 and #8 and Corn Field #6

FIELD & DATE	SPIKE HEIGHT	LEAF HEIGHT	% PLANT MOISTURE	% SOIL MOISTURE
W4 - June 10	NS	S**	NS	S**
W4 - June 17	S**	NS	S*	NS
W8 - June 10	NS	NS	NS	NS
W8 - June 17	S***	S***	S***	NS
C6 - June 17	S***	--	S*	S**
C6 - June 30	S**	--	NS	S**

NS = no significant difference between plots

S*, S**, S*** = 90, 95, 99% significance levels respectively

TABLE 4

Sample Size Estimates from Field Standard Deviation and Mean

FIELD #	DATE	VARIABLE	SAMPLE SIZE
W4	June 10	Spike HT	3
		Leaf HT	6
		Plant H ₂ O	5
		Soil H ₂ O	13
	June 17	Spike HT	9
		Leaf HT	9
		Plant H ₂ O	70
		Soil H ₂ O	6
W8	June 10	Spike HT	8
		Leaf HT	25
		Plant H ₂ O	13
		Soil H ₂ O	17
	June 17	Spike HT	18
		Leaf HT	37
		Plant H ₂ O	227
		Soil H ₂ O	34
C6	June 17	Spike HT	8
		Plant H ₂ O	1
		Soil H ₂ O	27
	June 30	Spike HT	3
		Plant H ₂ O	2
		Soil H ₂ O	20

TABLE 5(a)

**Mann-Whitney U Test for Between-
Field Variability of Wheat #4 and Wheat #8**

DATE	SPIKE HEIGHT	LEAF HEIGHT	% PLANT MOISTURE	% SOIL MOISTURE
June 10	NS	NS	S***	S***
June 17	S***	S***	S***	S***

TABLE 5(b)

**T-Test for Independent Samples of
Wheat #4 and Wheat #8**

DATE	SPIKE HEIGHT	LEAF HEIGHT	% PLANT MOISTURE	% SOIL MOISTURE
June 10	NS	NS	S***	S***
June 17	S***	S***	S***	S***

NS = no significant difference between means

S* = 99% significance level**

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TABLE 6(a)

Wilcoxon Matched-Pairs Ranked-Signs Test
for Within-Field Variability Over Time

FIELD	SPIKE HEIGHT	LEAF HEIGHT	% PLANT MOISTURE	% SOIL MOISTURE
W4	NS	NS	S***	S***
W8	S***	S***	S***	S***
C6	S***	--	S***	S***

TABLE 6(b)

T-Test for Related Samples to Determine
Within-Field Variability Over Time

FIELD	SPIKE HEIGHT	LEAF HEIGHT	% PLANT MOISTURE	% SOIL MOISTURE
W4	NS	S**	S***	S***
W8	S***	S***	S***	S***
C6	S***	--	S***	S***

NS = no significant difference between means

S** = 95% significance level

S*** = 99% significance level

APPENDIX

SPSS Computer Outputs for Statistical Tests

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SPSS 6.T.VARIABILITY

FILE NONAME (CREATION DATE = 10-21-81)

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

SH SPIKENT
BY PLOT PLOT

PLOT NUMBER	1	2	3
MEAN RANKS	6.33	10.50	11.67
CASES	18		
CHI-SQUARE	3.310		
SIGNIFICANCE		0.191	
CORRECTED FOR TIES			
CHI-SQUARE	3.390		
SIGNIFICANCE		0.184	

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

LH LEAFHT
BY PLOT PLOT

PLOT NUMBER	1	2	3
MEAN RANKS	4.92	11.50	12.08
CASES	18		
CHI-SQUARE	6.670		
SIGNIFICANCE		0.036	
CORRECTED FOR TIES			
CHI-SQUARE	6.760		
SIGNIFICANCE		0.034	

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

PW PLANTWATER
BY PLOT PLOT

PLOT NUMBER	1	2	3
MEAN RANKS	7.83	8.33	12.33
CASES	18		
CHI-SQUARE	2.561		
SIGNIFICANCE		0.278	
CORRECTED FOR TIES			
CHI-SQUARE	2.561		
SIGNIFICANCE		0.278	

SPSS 6.T.VARIABILITY

----- KRUSKAL-WALLIS 1-WAY ANOVA

BY SW SOILWATER
PLOT PLOT

PLOT NUMBER	1	2	3
MEAN RANKS	5.83	8.50	14.17
CASES	18		
CHI-SQUARE	7.626		
SIGNIFICANCE		0.022	

CORRECTED FOR TIES
CHI-SQUARE 7.626 SIGNIFICANCE 0.022

----- KRUSKAL-WALLIS 1-WAY ANOVA

BY SHB SPIKEHT2
PLOT PLOT

PLOT NUMBER	1	2	3
MEAN RANKS	13.50	10.58	4.42
CASES	18		
CHI-SQUARE	9.056		
SIGNIFICANCE		0.011	

CORRECTED FOR TIES
CHI-SQUARE 9.140 SIGNIFICANCE 0.010

----- KRUSKAL-WALLIS 1-WAY ANOVA

BY LHB LEAFHT2
PLOT PLOT

PLOT NUMBER	1	2	3
MEAN RANKS	8.92	11.83	7.75
CASES	18		
CHI-SQUARE	1.863		
SIGNIFICANCE		0.394	

CORRECTED FOR TIES
CHI-SQUARE 1.878 SIGNIFICANCE 0.391

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----- KRUSKAL-WALLIS 1-WAY ANOVA -----

PWB		PLANTWATER2			
BY PLOT		PLOT			
PLOT NUMBER		1	2	3	
MEAN RANKS		11.00	5.67	11.83	
CASES		18			
CHI-SQUARE		4.713			
SIGNIFICANCE			0.095		
		CORRECTED FOR TIES			
		CHI-SQUARE		SIGNIFICANCE	
		4.713		0.095	

----- KRUSKAL-WALLIS 1-WAY ANOVA -----

SWB		SOILWATER2			
BY PLOT		PLOT			
PLOT NUMBER		1	2	3	
MEAN RANKS		10.17	6.50	11.83	
CASES		18			
CHI-SQUARE		3.135			
SIGNIFICANCE			0.079		
		CORRECTED FOR TIES			
		CHI-SQUARE		SIGNIFICANCE	
		3.135		0.079	

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FILE NONAME (CREATION DATE = 10-21-81)

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

SH SPIKEHT
BY PLOT PLOT

PLOT	1	2	3		
NUMBER	6	6	6		
MEAN RANKS	7.25	8.42	12.83		
CASES	18	CHI-SQUARE	SIGNIFICANCE	CORRECTED FOR TIES	CHI-SQUARE SIGNIFICANCE
		3.652	0.161	3.671	0.160

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

LH LEAFHT
BY PLOT PLOT

PLOT	1	2	3		
NUMBER	6	6	6		
MEAN RANKS	7.17	8.50	12.83		
CASES	18	CHI-SQUARE	SIGNIFICANCE	CORRECTED FOR TIES	CHI-SQUARE SIGNIFICANCE
		3.696	0.158	3.704	0.157

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

PW PLANTWATER
BY PLOT PLOT

PLOT	1	2	3		
NUMBER	6	6	6		
MEAN RANKS	7.50	10.67	10.33		
CASES	18	CHI-SQUARE	SIGNIFICANCE	CORRECTED FOR TIES	CHI-SQUARE SIGNIFICANCE
		1.275	0.529	1.275	0.529

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----- KRUSKAL-WALLIS 1-WAY ANOVA

SW		SOILWATER				
BY PLOT		PLOT				
		1	2	3		
		6	6	6		
PLOT						
NUMBER						
MEAN RANKS		8.67	8.17	11.67		
CASES		18			CORRECTED FOR TIES	
			CHI-SQUARE	SIGNIFICANCE	CHI-SQUARE	
			1.509	0.470	SIGNIFICANCE	
					1.509	
					0.470	

----- KRUSKAL-WALLIS 1-WAY ANOVA

SHB		SPIKEHT2				
BY PLOT		PLOT				
		1	2	3		
		6	6	6		
PLOT						
NUMBER						
MEAN RANKS		4.75	9.33	14.42		
CASES		18			CORRECTED FOR TIES	
			CHI-SQUARE	SIGNIFICANCE	CHI-SQUARE	
			9.845	0.007	SIGNIFICANCE	
					9.845	
					0.007	

----- KRUSKAL-WALLIS 1-WAY ANOVA

LHB		LEAFHT2				
BY PLOT		PLOT				
		1	2	3		
		6	6	6		
PLOT						
NUMBER						
MEAN RANKS		3.50	10.50	14.50		
CASES		18			CORRECTED FOR TIES	
			CHI-SQUARE	SIGNIFICANCE	CHI-SQUARE	
			13.053	0.001	SIGNIFICANCE	
					13.093	
					0.001	

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- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

PWB		PLANTWATER2			
BY PLOT		PLOT			
		1	2	3	
PLOT		6	6	6	
NUMBER					
MEAN RANKS		4.00	10.33	14.17	
CASES		18			
			CHI-SQUARE	SIGNIFICANCE	
			11.099	0.004	
					CORRECTED FOR TIES
					CHI-SQUARE SIGNIFICANCE
					11.099 0.004

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

SWB		SOILWATER2			
BY PLOT		PLOT			
		1	2	3	
PLOT		6	6	6	
NUMBER					
MEAN RANKS		12.50	9.00	7.00	
CASES		18			
			CHI-SQUARE	SIGNIFICANCE	
			3.263	0.196	
					CORRECTED FOR TIES
					CHI-SQUARE SIGNIFICANCE
					3.263 0.196

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FILE NONAME (CREATION DATE = 10-21-81)

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

SH	SPIKEHT				
BY PLCT	PLOT				
PLOT	1	2	3		
NUMBER	6	6	6		
MEAN RANKS	11.25	13.08	4.17		
CASES	18				
CHI-SQUARE	9.336				
SIGNIFICANCE	0.009				
				CORRECTED FOR TIES	
				CHI-SQUARE	SIGNIFICANCE
				9.356	0.009

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

PW	PLANTWATER				
BY PLCT	PLOT				
PLOT	1	2	3		
NUMBER	6	6	6		
MEAN RANKS	6.67	13.42	8.42		
CASES	18				
CHI-SQUARE	5.167				
SIGNIFICANCE	0.076				
				CORRECTED FOR TIES	
				CHI-SQUARE	SIGNIFICANCE
				5.172	0.075

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

SW	SOILWATER				
BY PLCT	PLOT				
PLOT	1	2	3		
NUMBER	6	6	6		
MEAN RANKS	11.83	11.83	4.83		
CASES	18				
CHI-SQUARE	6.877				
SIGNIFICANCE	0.032				
				CORRECTED FOR TIES	
				CHI-SQUARE	SIGNIFICANCE
				6.877	0.032

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- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

BY	SHB PLOT	SPIKEHT2 PLOT			
	PLOT NUMBER	1 6	2 6	3 6	
MEAN RANKS		14.50	8.17	5.83	
	CASES	CHI-SQUARE	SIGNIFICANCE		
	18	8.468	0.014		
				CORRECTED FOR TIES	
				CHI-SQUARE	SIGNIFICANCE
				8.485	0.014

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

BY	PWB PLOT	PLANTWATER2 PLOT			
	PLOT NUMBER	1 6	2 6	3 6	
MEAN RANKS		9.17	11.33	8.00	
	CASES	CHI-SQUARE	SIGNIFICANCE		
	18	1.205	0.548		
				CORRECTED FOR TIES	
				CHI-SQUARE	SIGNIFICANCE
				1.205	0.548

- - - - - KRUSKAL-WALLIS 1-WAY ANOVA

BY	SWB PLOT	SOILWATER2 PLOT			
	PLOT NUMBER	1 6	2 6	3 6	
MEAN RANKS		12.83	4.83	10.83	
	CASES	CHI-SQUARE	SIGNIFICANCE		
	18	7.298	0.026		
				CORRECTED FOR TIES	
				CHI-SQUARE	SIGNIFICANCE
				7.298	0.026

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FILE NONAME (CREATION DATE = 10-21-81)

- - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

SH SPIKEHT
BY FIELD FIELD

FIELD MEAN RANK =
18.00

NUMBER 4
18

FIELD MEAN RANK =
19.00

NUMBER 8
18

U
153.0

W
324.0

EXACT
2-TAILED P
0.7905

CORRECTED FOR TIES
Z
-0.2859
2-TAILED P
0.7749

- - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

LH LEAFHT
BY FIELD FIELD

FIELD MEAN RANK =
20.72

NUMBER 4
18

FIELD MEAN RANK =
16.28

NUMBER 8
18

U
122.0

W
373.0

EXACT
2-TAILED P
0.2142

CORRECTED FOR TIES
Z
-1.2697
2-TAILED P
0.2042

- - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

PW PLANTWATER
BY FIELD FIELD

FIELD MEAN RANK =
25.00

NUMBER 4
18

FIELD MEAN RANK =
12.00

NUMBER 8
18

U
45.0

W
450.0

EXACT
2-TAILED P
0.0001

CORRECTED FOR TIES
Z
-3.7017
2-TAILED P
0.0002

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- - - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

SW BY FIELD	SOILWATER FIELD				
FIELD MEAN RANK	NUMBER	FIELD MEAN RANK	NUMBER		
27.50	4 18	9.50	8 18		
U	W	EXACT 2-TAILED P	CORRECTED FOR TIES 2-TAILED P		
0.	495.0	0.0000	-5.1255	0.0000	

- - - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

SHB BY FIELD	SPIKEHT2 FIELD				
FIELD MEAN RANK	NUMBER	FIELD MEAN RANK	NUMBER		
25.50	4 18	11.50	8 18		
U	W	EXACT 2-TAILED P	CORRECTED FOR TIES 2-TAILED P		
36.0	459.0	0.0000	-3.9950	0.0001	

- - - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

LHB BY FIELD	LEAFHT2 FIELD				
FIELD MEAN RANK	NUMBER	FIELD MEAN RANK	NUMBER		
25.17	4 18	11.83	8 18		
U	W	EXACT 2-TAILED P	CORRECTED FOR TIES 2-TAILED P		
42.0	453.0	0.0001	-3.8040	0.0001	

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- - - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

PWB BY FIELD	PLANTWATER2 FIELD				
FIELD MEAN RANK	NUMBER	FIELD MEAN RANK	NUMBER		
27.50	4 18	9.50	8 18		
U	W	EXACT 2-TAILED P	CORRECTED FOR TIES 2-TAILED P		
0.	495.0	0.0000	-5.1255		0.0000

- - - - - MANN-WHITNEY U - WILCOXON RANK SUM W TEST

SWB BY FIELD	SOILWATER2 FIELD				
FIELD MEAN RANK	NUMBER	FIELD MEAN RANK	NUMBER		
27.17	4 18	9.83	8 18		
U	W	EXACT 2-TAILED P	CORRECTED FOR TIES 2-TAILED P		
6.0	489.0	0.0000	-4.9356		0.0000

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FILE N0NAME (CREATION DATE = 10-21-81)

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

SH		SPIKEHT					
WITH SHB		SPIKEHT2					
CASES	TIES	13	-RANKS	5	+RANKS		2-TAILED P
18	0		MEAN		MEAN	-1.742	0.082
			9.65		9.10		

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

LH		LEAFHT					
WITH LHB		LEAFHT2					
CASES	TIES	10	-RANKS	5	+RANKS		2-TAILED P
18	3		MEAN		MEAN	-1.931	0.053
			9.40		5.20		

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

PW		PLANTWATER					
WITH PWB		PLANTWATER2					
CASES	TIES	16	-RANKS	2	+RANKS		2-TAILED P
18	0		MEAN		MEAN	-3.288	0.001
			10.06		5.00		

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

SW		SOILWATER					
WITH SWB		SOILWATER2					
CASES	TIES	1	-RANKS	17	+RANKS		2-TAILED P
18	0		MEAN		MEAN	-3.549	0.000
			4.00		9.82		

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FILE NONAME (CREATION DATE = 10-21-81)

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

SH SPIKEHT
WITH SHB SPIKEHT2

CASES	TIES	18 -RANKS	0 +RANKS		
18	0	MEAN	MEAN	2	2-TAILED P
		9.50	0.	-3.724	0.000

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

LH LEAFHT
WITH LHB LEAFHT2

CASES	TIES	16 -RANKS	2 +RANKS		
18	0	MEAN	MEAN	2	2-TAILED P
		10.31	3.00	-3.462	0.001

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

PW PLANTWATER
WITH PWB PLANTWATER2

CASES	TIES	18 -RANKS	0 +RANKS		
18	0	MEAN	MEAN	2	2-TAILED P
		9.50	0.	-3.724	0.000

- - - - - WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

SW SOILWATER
WITH SWB SOILWATER2

CASES	TIES	4 -RANKS	14 +RANKS		
18	0	MEAN	MEAN	2	2-TAILED P
		4.50	10.93	-2.940	0.003

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FILE NONAME (CREATION DATE = 10-21-81)

WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

SH		SPIKEHT					
WITH SHB		SPIKEHT2					
CASES	TIES	0	-RANKS	18	+RANKS		2-TAILED P
18	0		MEAN		MEAN	-3.724	0.000
			0.		9.50		

WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

PH		PLANTWATER					
WITH PWB		PLANTWATER2					
CASES	TIES	17	-RANKS	1	+RANKS		2-TAILED P
18	0		MEAN		MEAN	-3.680	0.000
			10.00		1.00		

WILCOXON MATCHED-PAIRS SIGNED-RANKS TEST

SW		SOILWATER					
WITH SWB		SOILWATER2					
CASES	TIES	1	-RANKS	17	+RANKS		2-TAILED P
18	0		MEAN		MEAN	-3.593	0.000
			3.00		9.88		

SPSS G.T. VARIABILITY

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PAGE 2

FILE NOBAME (CREATION DATE = 10-21-81)

T - T E S T														
GROUP 1 = FIELD		10	GROUP 2 = FIELD		10									
VARIABLE		NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	F VALUE	2-TAIL PROB.	POOLED VARIANCE ESTIMATE			SEPARATE VARIANCE ESTIMATE			
								T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	
SN	SPKENT													
	GROUP 1	18	99.9444	4.165	0.982	2.74	0.045	-0.41	34	0.685	-0.41	27.96	0.685	
	GROUP 2	18	100.7222	6.892	1.625									
LN	LEAFNT													
	GROUP 1	18	72.9444	4.359	1.027	3.63	0.011	1.36	34	0.184	1.36	25.70	0.186	
	GROUP 2	18	69.9444	8.306	1.958									
PM	PLANTWATER													
	GROUP 1	18	54.8133	2.928	0.698	1.89	0.198	4.83	34	0.000	4.83	31.84	0.000	
	GROUP 2	18	48.3334	4.029	0.950									
SW	SOILWATER													
	GROUP 1	18	34.2017	2.867	0.676	1.90	0.193	15.58	34	0.000	15.58	31.80	0.000	
	GROUP 2	18	21.2000	2.078	0.490									
SND	SPKENT2													
	GROUP 1	18	96.0000	6.730	1.586	1.52	0.399	5.01	34	0.000	5.01	32.62	0.000	
	GROUP 2	18	83.3889	8.290	1.954									
LND	LEAFNT2													
	GROUP 1	18	69.3333	4.851	1.143	3.06	0.027	4.51	34	0.000	4.51	27.85	0.000	
	GROUP 2	18	58.9444	8.482	1.999									
PND	PLANTWATER2													
	GROUP 1	18	41.5000	8.163	1.924	1.38	0.515	8.59	34	0.000	8.59	33.16	0.000	
	GROUP 2	18	19.5833	6.951	1.538									

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FILE NO. NAME (CREATION DATE = 10-21-81)

T - T E S T												

GROUP 1 = FIELD 10 4												
GROUP 2 = FIELD 10 4												
VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	F VALUE	2-TAIL PROB.	* POOLED VARIANCE ESTIMATE *			* SEPARATE VARIANCE ESTIMATE *		
							T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
SUB	10											
GROUP 1	10	37.8194	2.089	0.692								
GROUP 2	10	24.1561	3.340	0.787	2.55	0.061	14.72	34	0.000	14.72	28.54	0.000

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SPSS G.T. VARIABILITY

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FILE MONAME (CREATION DATE = 10-21-81)

----- T - T E S T -----												
VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
SH	SPKENT	99.9444	4.165	0.982	:	:	:	:	:	:	:	:
	18	96.0000	6.730	1.586	:	3.9444	9.076	2.140	-0.353	0.153	1.04	0.065
SHB	SPKENT2				:	:	:	:	:	:	:	:
LN	LEAFNT	72.9444	4.359	1.027	:	:	:	:	:	:	:	:
	18	69.3333	4.851	1.143	:	3.6111	6.740	1.589	-0.069	0.787	2.27	0.036
LNH	LEAFNT2				:	:	:	:	:	:	:	:
PU	PLANTWATER	54.0133	2.928	0.690	:	:	:	:	:	:	:	:
	18	41.5000	8.163	1.924	:	12.7128	8.421	1.985	0.098	0.724	6.40	0.000
PUH	PLANTWATER2				:	:	:	:	:	:	:	:
SH	SOILWATER	34.2017	2.867	0.676	:	:	:	:	:	:	:	:
	18	37.8194	2.889	0.692	:	-3.6178	3.236	0.763	0.176	0.484	-4.74	0.000
SHB	SOILWATER2				:	:	:	:	:	:	:	:

FILE NO:NAME (CREATION DATE = 10-21-81)

----- T - T E S T -----													
VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	2-TAIL PRCB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.		
SH	SPIKENT	100.7222	6.892	1.625	17.3333	8.630	2.034	0.365 0.136	8.52	17	0.000		
	18	83.3889	8.290	1.954									
SHB	SPIKENT2				11.0000	8.872	2.091	0.442 0.067	5.26	17	0.000		
LN	LEAFHT	69.9444	8.306	1.958									
	18	58.9444	8.482	1.999	28.7561	7.390	1.742	0.177 0.482	16.51	17	0.000		
LNb	LEAFHT2												
PM	PLANTWATER	48.3394	4.029	0.950	-2.9561	4.133	0.974	0.116 0.445	-3.03	17	0.007		
	18	19.5833	6.951	1.638									
PNB	PLANTWATER2				-2.9561	4.133	0.974	0.116 0.445	-3.03	17	0.007		
SM	SOILWATER	21.2000	2.078	0.490									
	18	24.1561	3.340	0.787	-2.9561	4.133	0.974	0.116 0.445	-3.03	17	0.007		
SNB	SOILWATER2												

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FILE NONAME (CREATION DATE = 10-21-81)

- T - T E S T -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	2-TAIL CORR. PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
SM	SPIKENT	182.6111	12.258	2.889							
	18	269.3889	10.760	2.536	-86.7778	14.862	3.503	0.171 0.497	-24.77	17	0.000
SMQ	SPIKENT2										
PM	PLANTWATER	91.6211	1.016	0.239							
	18	82.7228	2.576	0.607	8.8983	2.968	0.700	-0.218 0.384	12.72	17	0.000
PMQ	PLANTWATER2										
SW	SOILWATER	20.7972	2.548	0.601							
	18	26.3233	2.769	0.653	-5.5261	4.039	0.952	-0.153 0.546	-5.81	17	0.000
SWQ	SOILWATER2										